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Technical Memorandum
Chemicals of Potential Concern to Sample for Soil and Vegetation
at Ballard, Henry, and Enoch Valley Mines

Below is the Agency and Tribal direction, along with the rationale, for analytes to be sampled for soil and vegetation on waste rock dumps and mine pits at Ballard, Henry, and Enoch Valley mines. Briefly, a list of chemicals of potential concern (COPCs) was compiled from several sources. These COPCs were then compared to human health and ecological soil screening levels. COPCs that exceeded any screening level or for which data were limited were included in the list of analytes that need to be sampled as part of the soil investigation.

Soil

Chemicals of Potential Concern
The Area Wide Human Health and Ecological Risk Assessment (2002; AWHHERA) evaluated several elements in waste rock. These elements included: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, uranium, vanadium, and zinc. It should be noted that the AWHHERA evaluated waste rock pile surface soil from the perspective of soil inhalation not soil ingestion.

In 2001, the USGS published a report that examined the chemical composition of waste rock dumps in Idaho, Wyoming, and Utah. Moyle and Causey (2001) documented seven contaminants whose average concentration was moderately (1.5-5.6 times) elevated above the world-wide average for shale. These contaminants included: arsenic, antimony, thallium, chromium, copper, nickel, and vanadium. In addition, four other contaminants – selenium, cadmium, molybdenum, and zinc – greatly (12-172 times) exceeded the world-wide shale average.

Ford (2004) looked at risk management for metals at BLM mining sites. Eleven contaminants of concern were identified by Ford for human health risk: antimony, arsenic, cadmium, copper, lead, manganese, mercury, nickel, selenium, silver, and zinc. Arsenic, cadmium, copper, lead, mercury, and zinc were included in the ecological assessment.

Other reports (McKelvey and Carswell (1967), Hovland and Moore (1986), Gillerman (nda)) have identified high levels of some of the same aforementioned elements in the Phosphoria Formation including: chromium, selenium, silver, uranium, vanadium, and zinc. These elements appear to be for the most part more concentrated in the phosphate zones.

Human Health and Ecological Screening Levels
Based on the above, twenty-two COPCs were chosen to evaluate against human health (ORNL website) and ecological (EPA website and ORNL [Sample et al. 1996]) soil screening levels (Table 1). The ORNL ecological soil screening levels were only applied

to those chemicals (mercury, molybdenum, and uranium) for which there were soil concentration data and no EPA ecological soil screening levels. The analytes compared to soil screening levels included: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, uranium, vanadium, and zinc. Iron was added to the list because soil screening levels were available.

Maximum concentrations of these COPCs observed at the three mines during five sampling events (Table 2) were then compared to human health and ecological soil screening levels (eco-SSL). Note that although aluminum was sampled the data were considered unusable, and boron and cobalt were not sampled. Chromium was not speciated so no comparison was possible without assuming some ratio of CrIII to CrVI. Four chemicals (arsenic, cadmium, manganese, and vanadium) exceeded human health screening levels for at least one of the mines (Table 3). Concentrations exceeding ecological screening levels were much greater than exceedances for human health. Maximum concentrations of antimony, arsenic, cadmium, copper, mercury, manganese, molybdenum, nickel, selenium, silver, uranium, vanadium, and zinc were greater than at least one eco-SSL. Barium, beryllium, and lead did not exceed either human health or ecological soil screening levels. Neither iron nor thallium exceeded human health screening levels. Specific ecological soil screening levels were not calculated for iron and no ecological soil screening levels were found for thallium.

Residential scenario

Unless evidence can be shown to the contrary, a residential use scenario must be considered for the three mines. The human health risk assessment will evaluate for residential use at the mine sites, including waste rock dumps.

The risks associated with uranium and its radioactive daughter products are a data gap that must be acknowledged in the workplan and addressed in the risk assessment. The chemical toxicity of uranium as well as the radiogenic toxicity of uranium-238 decay products warrants the inclusion of uranium in the risk assessment as a COPC. As noted in the Area Wide Risk Management Plan (IDEQ 2004), there is an elevated risk to human health from radium-226 when a residential scenario is considered. Such a scenario means that other chemicals of potential concern, such as daughter products of uranium (e.g., radium-226, radon-222, lead-210, and polonium-210) may be associated with unacceptable radiogenic risk under certain exposure scenarios and need to be considered.

Mass concentration of uranium can be used to estimate activity concentration of its daughter products for risk assessment. As an alternative to use of uranium mass concentration to estimate daughter product activity concentration, the Agencies and Tribes will consider radiogenic risks estimated through use of the RESRAD computer code.

In addition to sampling for mass concentration of uranium, the Agencies and Tribes recommend limited monitoring for Ra-226. We believe that sampling for Ra-226 will help validate estimates of Ra-226 based on mass concentrations of uranium.

Vegetation

Ford (2004) assumed that ingestion of soil, sediment, and plants to be the predominant source of exposure of metals for wildlife receptors. It follows that any COPC for soil should also be included as a COPC for vegetation.

Recommended List of Analytes for Soil and Vegetation Sampling

From the 22 COPCs screened for human health and ecological screening levels, the following are required for evaluation as part of the sampling of soil and vegetation at waste rock dumps and mine pits at Ballard, Henry, and Enoch Valley mines: antimony, arsenic, boron, cadmium, chromium, cobalt, copper, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, uranium (radium-226), vanadium, and zinc (Table 4). Most of the COPCs on the list of analytes to sample exceeded either human health and/or ecological soil screening levels. Boron and cobalt were retained as there currently are no applicable screening levels to evaluate the potential for unacceptable human health or ecological risk. Because of the need for information on the various valence states of chromium (i.e., CrIII and CrVI), it was kept on the list of analytes to sample. Thallium was included as data for this metal is necessary for use in ecological risk assessment. Barium, beryllium, and lead were eliminated as they did not exceed any human health or ecological screening level. Limited data (Tetra Tech EM 2002) from waste rock dumps at the three mines indicate soil pH is greater than 5.5, so aluminum was eliminated from consideration. Iron was also dropped as there was no indication that it is a problem in the area.

There are other factors that were considered for the inclusion of molybdenum and uranium. Molybdenum is an additional concern based on its interaction with copper and the potential for molybdenosis. Uranium data are necessary to estimate risk from its various daughter products, especially from a residential scenario.

Changes to List of Analytes

The list of analytes to sample for soil and vegetation at Henry, Ballard, and Enoch Valley mines is based on information available to the Agencies and Tribes. We would entertain removing additional contaminants from the list if P4/Monsanto can provide an adequate technical basis for doing so (e.g., screening available representative data against applicable risk based benchmarks). Furthermore, the Agencies and Tribes would be open to other accepted means with which to estimate concentrations of metals/metalloids in vegetation, such as from soil concentrations.

Table 1. Soil screening levels for human health and ecological receptors.

COPC	ORNL human health soil screening levels[1] (mg/kg)		Eco-SSL[2] (mg/kg)				ORNL ecological soil screening levels[3] (mg/kg)	
	Residential	Industrial	Plants	Soil inverts	Avian	Mam-malian	Avian	Mam-malian
Aluminum	77,000	990,000	NV	NV	NV	NV	NA[4]	NA[4]
Antimony	31[5]	410[5]	NA	78	NA	0.27	NA	0.25
Arsenic	0.39[6]	1.6[6]	18	NA	43	46	2	0.25
Barium	15,000	190,000	NA	330	NA	2,000	17.2	19.7
Beryllium	160[7]	2,000[7]	NA	40	NA	21	NA	2.4
Boron	16,000[8]	200,000[8]	NoSL	NoSL	NoSL	NoSL	24	103
Cadmium	70[79]	810[79]	32	140	0.77	0.36	1.2	3.5
Chromium III	120,000[10]	1,500,000[10]	NA	NA	26	34	0.83	10,000
Chromium VI	230[11]	1,400[11]	NA	NA	NA	130	NA	12
Cobalt	NoSL	NoSL	13	NA	120	230	NA	NA
Copper	3,100	41,000	70	80	28	49	38.9	55.7
Iron	55,000	720,000	NV	NV	NV	NV	NA	NA
Lead	400[7]	NoSL[7]	120	1,700	11	56	0.9	29.3
Manganese	1,800[12]	23,000[12]	220	450	4300	4000	825	322
Mercury	7[13]	28[13]	NoSL	NoSL	NoSL	NoSL	0.4	4.7
Molybdenum	390	5,100	NoSL	NoSL	NoSL	NoSL	2.9	0.5
Nickel	1,600[14]	20,000[14]	38	280	210	130	64	147
Selenium	390	5,100	0.52	4.1	1.2	0.63	0.33	0.73
Silver	390	5,100	560	NA	4.2	14	NA	NA
Thallium	5[14]	66[14]	NoSL	NoSL	NoSL	NoSL	NA	NA
Uranium	230[14]	3,100[14]	NoSL	NoSL	NoSL	NoSL	21	6
Vanadium	390[7]	5,200[7]	NA	NA	7.8	280	9.4	0.7
Zinc	23,000[5]	310,000[5]	160	120	46	79	12	586

NA=not available, data insufficient to derive Eco-SSL
NV=no set value, number varies
NoSL=no screening level
[1]Oak Ridge National Laboratory screening levels for chemical contaminants
[2]EPA ecological soil screening levels
[3]calculated from lowest reported NOAEL-Based Benchmark for food from Oak Ridge National Laboratory Toxicological Screening Benchmarks for Wildlife (Sample et al. 1996)
[4]aluminum is only a concern when soil pH<5.5
[5]metallic
[6]inorganic
[7]and compounds
[8]and borates only
[9]in diet
[10]insoluble salts
[11]particulates
[12]in water
[13]elemental
[14]soluble salts

Table 2. Maximum concentrations (mg/kg dw) observed during various sampling events at Ballard, Henry, and Enoch Valley mines. Note that many of these results are estimated quantities. In 2004 for some analytes the extractable fraction was analyzed, those data are not included.

Site	Sampling event	Metal/metalloid (mg/kg dw)																			
		Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Tl	U	V	Zn
Ballard	1998	--	--	--	--	--	49	--	--	20,000	--	310	--	--	300	240	--	--	--	370	1400
	2001 - May	--	13	43	100	1.8	120	1100	150	--	10	48	0.56	28	280	110	9.1	<2.0	--	800	1600
	2001 - Aug-Sep	du	3.5	23	140	1.7	du	640	87	--	du	410	0.39	--	200	24	4.5	1.5	51	530	930
	2004	--	--	--	--	--	--	--	--	--	--	--	--	--	--	71	--	--	--	--	220
Henry	2001 - May	--	17	50	110	1.6	31	1100	140	--	11	280	0.69	39	420	39	7.2	<2.0	--	310	1500
	2001 - Aug-Sep	du	6.9	du	120	1.9	du	770	140	--	du	500	0.54	--	320	19	4.2	1.6	39	330	1100
	2004	--	--	--	--	--	--	--	--	--	--	--	--	--	--	53	--	--	--	--	--
Enoch Valley	2000 - Summer	--	--	--	--	--	94	--	--	38,000	--	6100	--	--	480	360	--	--	--	830	3100
	2001 - May	--	23	57	170	2.0	42	1400	170	--	<8.1	110	0.87	41	400	61	6.2	<2.0	--	510	1700
	2001 - Aug-Sep	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	42	--	--
	2004	--	--	--	--	--	--	--	--	--	--	--	--	--	--	140	--	--	--	--	--

--=not sampled or not applicable

<=the material was analyzed for, but was not detected above the level of the associated value. The associated value is the sample reporting limit.

du=data unusable

Table 3. Occurrence of exceedances of soil screening levels of various contaminants from 1998, 2000, 2001, and 2004 sampling events at Ballard, Henry, and Enoch Valley mines.

COPC	Screening level exceedance of maximum observed value														
	Ballard Mine					Henry Mine					Enoch Valley Mine				
	Human health	Plants	Soil inverts	Avian	Mammalian	Human health	Plants	Soil inverts	Avian	Mammalian	Human health	Plants	Soil inverts	Avian	Mammalian
Aluminum	du	du	du	du	du	du	du	du	du	du	du	du	du	du	du
Antimony	No	--	No	--	**Yes**	No	--	No	--	**Yes**	No	--	No	--	**Yes**
Arsenic	**Yes**	**Yes**	--	**Yes**	No	**Yes**	**Yes**	--	**Yes**	**Yes**	**Yes**	**Yes**	--	**Yes**	**Yes**
Barium	No	--	No	--	No	No	--	No	--	No	No	--	No	--	No
Beryllium	No	--	No	--	No	No	--	No	--	No	No	--	No	--	No
Boron	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cadmium	**Yes**	**Yes**	No	**Yes**	**Yes**	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**
Chromium	No	--	--	**Yes**	**Yes**	No	--	--	**Yes**	**Yes**	No	--	--	**Yes**	**Yes**
Cobalt	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Copper	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**
Iron	No	--	--	--	--	--	--	--	--	--	No	--	--	--	--
Lead	No	No	No	No	No	No	No	No	**Yes**	No	No	No	No	No	No
Manganese	No	**Yes**	No	No	No	No	**Yes**	**Yes**	No	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Mercury	No	--	--	**Yes**	No	No	--	--	**Yes**	No	No	--	--	**Yes**	No
Molybdenum	No	--	--	**Yes**	**Yes**	No	--	--	**Yes**	**Yes**	No	--	--	**Yes**	**Yes**
Nickel	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**
Selenium	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**
Silver	No	No	--	**Yes**	No	No	No	--	**Yes**	No	No	No	--	**Yes**	No
Thallium	No	--	--	--	--	No	--	--	--	--	No	--	--	--	--
Uranium	No	--	--	**Yes**	**Yes**	No	--	--	**Yes**	**Yes**	No	--	--	**Yes**	**Yes**
Vanadium	**Yes**	--	--	**Yes**	**Yes**	No	--	--	**Yes**	**Yes**	**Yes**	--	--	**Yes**	**Yes**
Zinc	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**

du=data unusable so no comparison possible

--=no comparison possible due to screening levels unavailable or no data available from the mines

[1]assumes 6:1 ratio of CrIII:CrVI (EPA, Region 9, PRG; Jeff Fromm [IDEQ] personal communication)

Table 4. List of analytes to be analyzed for soil and vegetation sampling on waste rock dumps and mine pits at Ballard, Henry, and Enoch Valley mines.

COPC	Comments
Antimony	
Arsenic	
Boron	
Cadmium	
Chromium	Speciation required of a subset of samples
Cobalt	
Copper	
Manganese	
Mercury	
Molybdenum	
Nickel	
Selenium	
Silver	
Thallium	
Uranium	Will also be used to estimate Ra-226, some sampling of Ra-226 recommended
Vanadium	
Zinc	

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